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North Sea Hydrogen Valley Ports

Creating the hydrogen corridor between North Sea ports

Deliverable D 2.3

Development of Methodology for Master Plans

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Contents

Abbreviations

CAPEX	Capital Expenditures
PPP	Public–Private Partnership
ROI	Return on Investment
H_2	Hydrogen
ISL	Institute for Sustainable Logistics
LUSAC	Le Havre University

Executive summary

The North Sea region's ambition to create a transnational hydrogen corridor hinges on the capacity of individual ports to develop robust and economically sound strategies. Deliverable D2.3 provides the definitive, multi-phase Methodology for Master Plan Development, ensuring that the four participating ports (Bremen, Brest, Den Helder, and Esbjerg) transition successfully from conceptual goals to implementable projects.

The process mandates a structured progression, beginning with the Preparatory and Analytical Phases for defining objectives, mapping the port ecosystem, and gathering essential data on energy needs and regulatory landscapes. The technical core relies on a two-tiered optimization strategy.

The first tier is Local Optimization, which uses computationally light algorithms (e.g., linear programming) to calculate the optimal sizing and configuration of local assets, such as electrolysers and storage, thereby minimizing capital expenditure (CAPEX) within specific technical constraints. The second tier, Global Optimization, elevates this planning to the regional level, coordinating hydrogen exchange and logistics across the North Sea hub to maximize overall system efficiency and resilience. This comprehensive modeling informs the final Planning Phase, where technical findings, economic analysis, and governance aspects are synthesized into a coherent, bankable Master Plan.

1. Introduction

The NS H2V ports project aims to facilitate and develop green hydrogen production, storage, delivery, and use in the North Sea ports. In line with this framework, Activity 2.3 of WP2 provides methodology to support green-ports' coalition in Master Plan development. This document is a structured approach in a step-by-step process to implement strategies and support making decisions on task definition and resource allocations; the resulting template of which will be adapted/implemented to each port.

2. Methodology for Hydrogen Valley Ports Master Plan creation

As part of the development of a methodology for Port Hydrogen Valley Master Plans, the process and steps required to create a master plan will be addressed. The aim is to develop a systematic approach that can serve as a guide for others to create a master plan for a Port Hydrogen Valley and enable concrete planning and implementation.

The planned methodology comprises 7 phases as depicted in Figure 1 and explained in the sections below.

2.1. Preparatory Phase

As part of a preparatory phase, the relevant stakeholders (port authorities, industry partners, governments, research institutions, municipalities) are identified and involved in the planning process. In addition, clear goals and expectations for the Port Hydrogen Valley should be defined. This also includes ecological, economic, and social aspects.

2.2. Analytical Phase

In this phase, a comprehensive examination of the current situation is carried out. This includes the existing infrastructure, the available resources (renewable energies), and the technological and regulatory framework conditions. In addition, demand analyses are carried out to identify hydrogen demand in the port and neighbouring industries. Future demand forecasts are also taken into account. The analytical phase is further discussed in Chapter 3.

2.3. Planning Phase

In this phase, plans are developed for hydrogen production, storage, and distribution. Various technologies (electrolysis, storage in pressurized tanks or underground storage facilities, pipelines, etc.) are considered. In addition, the best locations for the hydrogen infrastructure are determined, taking logistical, economic, and ecological factors into account.

2.4. Economic Analysis

The economic benefits and costs of the proposed projects are determined and evaluated as part of an economic analysis. Investment costs, operating costs, and potential sources of revenue are taken into account. Possible sources of funding, including public subsidies, private investment, and public-private partnerships (PPP), are also identified.

2.5. Regulatory and Governance Aspects

Existing regulatory framework conditions are analysed, and potential obstacles and bottlenecks are identified. Strategies can also be developed to overcome these challenges. This also includes, for example, a governance structure that defines clear responsibilities and decision-making processes.

2.6. Implementation phase

In the implementation phase, detailed project plans with timetables and responsibilities are developed. It also makes sense to define milestones. In addition, potential risks and strategies to avoid or mitigate them should be considered.

2.7. Monitoring and evaluation

As part of monitoring and evaluation, indicators should be developed to monitor progress and assess the achievement of objectives. In addition, mechanisms for regular review and adjustment of the master plan based on the knowledge gained and changed framework conditions are relevant in this context.

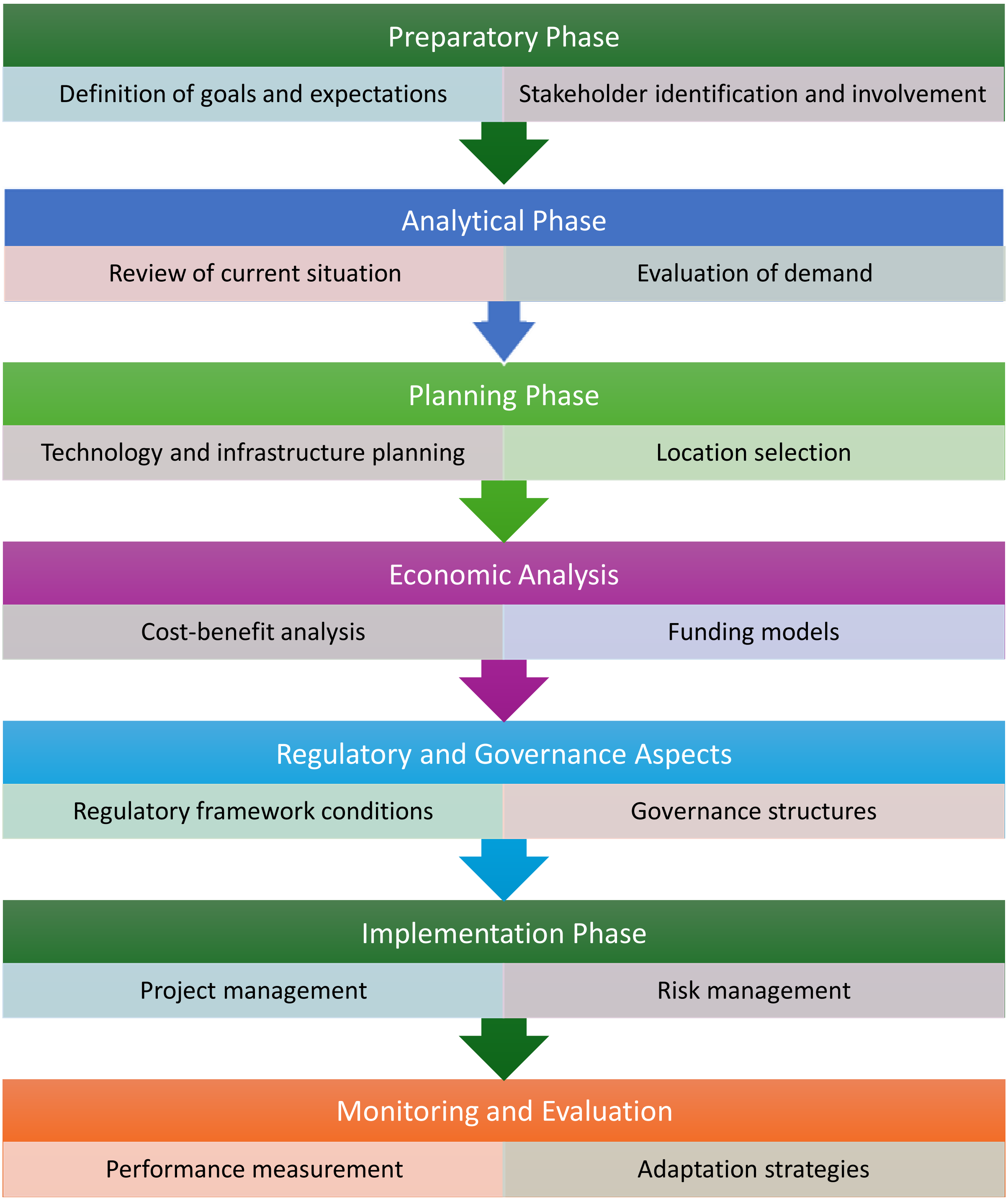

Figure 1: Methodology for Hydrogen Valley Ports Master Plan Creation

3. Principles of Data Analysis and Modelling Techniques for Master Plan Development

This chapter outlines the structured approach used for data analysis and modelling within the Master Plan for hydrogen integration in port ecosystems. It begins with a preparatory phase focused on collecting and classifying qualitative and quantitative data, followed by the analysis of the data, and lastly optimization, both at a local and global level. The chapter provides the analytical foundation for strategic planning, scenario evaluation, and economic assessment in the Master Plan.

3.1. A structured approach to data analysis

A structured approach to data analysis begins with a comprehensive data collection phase aimed at defining the port ecosystem, its needs, and constraints. This initial step, referred to as the preparatory phase, is essential to establishing a detailed understanding of each port's long-term strategies, governance structures, key actors (such as energy suppliers and investors), and critical influencing factors (such as regulations and incentives).

The preparatory phase serves as a "state of the art" assessment of each port's scope, infrastructure, technologies, and strategic objectives. It also identifies potential benefits, barriers, and risks related to hydrogen market deployment. Crucially, this phase defines the broader port environment—including both physical systems and policy strategies—by mapping out the energy landscape and hydrogen-related priorities. These are then translated into concrete actions, milestones, and required equipment or services, based on guidance from local authorities.

Collected data is categorized into two main types: qualitative and quantitative. Qualitative data, often descriptive and contextual, are used to develop evaluation matrices and hierarchical structures to support decision-making and comparative studies. Quantitative data, on the other hand, is used to build and calibrate simulation models.

Data collection activities are conducted through partner collaboration as part of Activity 1.2 of WP1 and Activity 2.3 of WP3. The analytical phase lies at the core of the Master Plan's development process, feeding into both the economic evaluation and comparative assessments used to validate the proposed strategies.

3.2. Qualitative Data Analysis

The analysis of qualitative data involves systematically identifying relevant information, removing redundancies, and filtering out insignificant content. This process is guided by a clear methodological structure to ensure consistency and depth.

The initial step is to define a set of key topics, key factors, and key actors, which serve as the foundation for classification. From there, data is grouped into clusters based on shared characteristics, using data clustering techniques. Within each cluster, features are defined to describe qualitative behavior, and an **evaluation grid** is used to rate the perceived significance or influence of each feature.

Each feature is assigned a quantitative weight to enable comparison and ranking. Frequency of occurrence and inter-feature correlations are also examined to reduce duplication and eliminate low-value data. Once weighted, the data is structured hierarchically, which supports downstream activities such as priority setting, risk assessment, and comparative analysis.

This method is especially effective for organizing complex qualitative inputs and drawing insights for strategic planning. Quantitative data, meanwhile, is reserved for more advanced modelling and optimization processes as described in section 3.3.

3.3. Port modelling (quantitative data analysis)

Port modelling is the process of developing a mathematical representation of a port's energy system. This includes all major energy installations and their interactions within the port ecosystem. The objective is to create a model that is both accurate and computationally efficient, capable of simulating dynamic energy behavior without excessive complexity.

Each energy subsystem—such as battery storage, hydrogen tanks, and energy generation units—is described using equations that link inputs, outputs, and internal states (e.g., state of charge, hydrogen pressure). The model also incorporates contextual data such as port strategy, stakeholder priorities, and regulatory factors.

Model fitting is used to calibrate the parameters based on historical or real-time data, creating a virtual representation of the port known as the **"port avatar"**. This avatar is then used to test various energy scenarios and identify the best strategies for optimizing the hydrogen value chain.

3.3.1. Local optimization

A well-calibrated port avatar is crucial for performing local optimization, which aims to determine the best sizing and configuration of energy systems under a defined set of technical, financial, and operational constraints.

This includes estimating hydrogen production and consumption (both local and imported/exported), calculating performance indicators, and evaluating economic outcomes such as capital costs, cash flows, return on investment (ROI), and payback periods.

Local optimization typically employs linear programming or equivalent mathematical methods to minimize or maximize an objective function, such as cost or system efficiency. Constraints—including power limitations, budget caps, and energy balance requirements—are formulated as linear equations or inequalities.

The selected algorithm is designed to be simple, flexible, and computationally light, making it suitable for long-term simulations. If available, additional factors such as equipment aging and maintenance costs can also be integrated into the analysis.

3.3.2. Global optimization

While local optimization focuses on individual port systems, global optimization addresses the coordination of multiple ports operating as a connected hub. In this scenario, four ports share infrastructure and resources to enhance overall system efficiency and economic viability.

Each port operates as an independent agent with its own localized objectives, but also contributes to the global energy and cost balance of the hub. The hub's optimization process begins by evaluating local priorities. If no conflicts or constraints are identified, the hub request is validated and incorporated into the local optimization process by adjusting local targets. If conflicts arise, an alert is issued, and alternative configurations are explored.

The primary aim of global optimization is to maximize hydrogen exchange across the North Sea ports, balancing local objectives with regional synergies. This includes optimizing hydrogen flows based on import/export needs, transportation methods (pipelines, vessels, etc.), distances, and timing—ensuring cost-effective and resilient inter-port operations.

4. Conclusion

The methodology presented in this report represents a significant step forward, transforming the regional hydrogen corridor concept from a vision into a series of actionable, optimized Master Plans. The key innovation lies in the tiered modeling strategy.

The Local Optimization process provides the foundational, economic viability for each of the four North Sea ports, ensuring that the design and sizing of hydrogen assets minimize initial investment costs and fit within existing power and budget limitations. The computational efficiency of this model allows for robust long-term simulation and risk assessment.

However, the real added value comes from Global Optimization, which coordinates the exchange of hydrogen across the hub. By balancing local objectives with regional supply and demand, this step maximizes inter-port trade and logistics, ensuring the cost-effective and resilient operation of the entire network. This comprehensive framework is crucial for accelerating the transition and positioning the North Sea region at the forefront of the commercial green hydrogen market before the end of the decade.